Observing the Reaction Kinetics of Sucrose with Polarimetry

1. This experiment is written for data collection with the Vernier Go Direct Polarimeter and one of the following:
   - Instrumental Analysis app (version 1.2 or newer) running on a computer, Chromebook, or mobile device
   - LabQuest 3 (app version 3.0.3 or newer)
   - LabQuest 2 (app version 2.8.7 or newer)

   Visit **www.vernier.com/downloads** for information about how to download the most recent version for your device.

2. Sucrose is often used as a calibration standard for polarimeters, which is why it is suggested in this experiment. You may also use other sugars and should obtain similar results for Part I.

3. Literature values for specific rotation were obtained from the CRC Handbook, determined in water at concentrations of 1–5 g per 100 mL of solution, at 20–25°C, and at 589 nm.

4. Invertase can be purchased from most chemical supply companies. However, you can also isolate invertase from baker's yeast by doing the following: mix half a package of baker's yeast with 40 mL of distilled water and centrifuge the mixture for 5 minutes. Decant the top layer; the remaining bottom layer is crude invertase enzyme.

5. Invertase concentrations listed in the student guide are highly dependent on the activity of the enzyme, which varies based on manufacturer and species. Therefore, the concentrations listed are simply guidelines that produced the sample results below. It is strongly suggested that you run the experiment beforehand to ensure the proper concentrations for your specific enzyme.

6. If you would like your students to linearize the data to determine the reaction order instead of using a nonlinear fit, you will need to reduce the concentrations of acid and invertase used. The experiment is currently designed to get an exponential decay quickly. To use the method of initial rates, you should try 1 M HCl and 5 mg/mL invertase. The change in angle of rotation will not be as obvious here and the reaction will need to be watched for a longer period of time.

7. There are several ways to locate the angle at which the maximum illumination occurs:

   Using Instrumental Analysis

   a. Statistics: To simply get the angle with the highest illumination, highlight the peak of interest in Instrumental Analysis, as shown in Figure 1. Click or tap Graph Tools, , and select View Statistics. Record the angle value where the illumination is at a maximum, as presented in the box. This method is the fastest and will result in reproducibility of the angle of rotation measurement of ±2.0°.

b. Examine: Click or tap the Illumination *vs*. Angle graph to find the data point associated with the peak that is closest to 0°. This method also lacks accuracy but is useful from a pedagogical standpoint as it connects the feature on the graph in a way that telling students to perform a curve fit and use the parameters does not.

c. Cosine Squared: To incorporate all of the data into the fit, students can fit the data to its true waveform, a cosine squared, in Instrumental Analysis. Choose Curve Fit from the Graph Tools, . From the list of available General Equations, select Cosine Squared. The fit will run automatically. In this fit, the x-value corresponding to the maximum y-value is obtained from the negative of the phase shift parameter, –C. This is a nonlinear fit which undergoes numerous iterations and has the possibility of no convergence, which will result in an unreasonable answer. With all nonlinear fits, it is important to make sure the resulting value is reasonable based on the data presented in the graph. This method is the most time consuming; however, it will result in reproducibility of the angle of rotation measurement of ±0.1°.

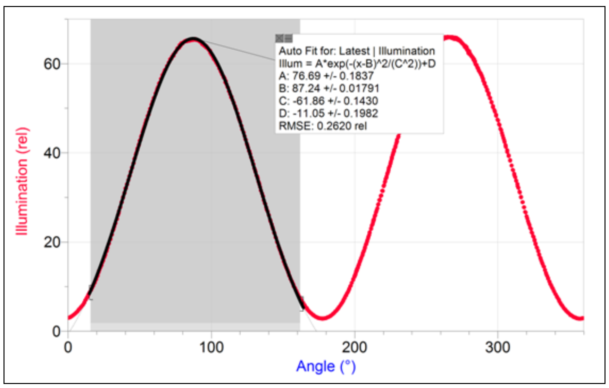

Figure 1 Selection for Statistics and Gaussian fits (applies to all supported software)

Using LabQuest 2 or 3

a. Statistics: To simply get the angle with the highest illumination, highlight the peak of interest in LabQuest App, as shown in Figure 1. Choose Statistics from the Analyze menu. Record the angle value where the illumination is at a maximum, as presented in the box. This method is the fastest and will result in reproducibility of the angle of rotation measurement of ±2.0°.

b. Gaussian: To improve your accuracy with a better fit, highlight the peak of interest using LabQuest App, as shown in Figure 1. Then, choose Curve Fit from the Analyze menu. From the list of available Equations, select Gaussian. The fit will run automatically. The B coefficient presented represents the angle at maximum illumination. This method will result in reproducibility of the angle of rotation measurement of ±0.3°. The data are not a true Gaussian, but the ease and accuracy of this methodology make it a good option. For best results, be consistent in the way you select your peaks.

c. Cosine Squared: To incorporate all of your data into the fit, you can fit the data to its true waveform, a cosine squared, in LabQuest App. Choose Curve Fit from the Analyze menu. From the list of available General Equations, select Cosine Squared. The fit will run automatically. In this fit, the x-value corresponding to the maximum y-value is obtained from the negative of the phase shift parameter, –C. This is a nonlinear fit which undergoes numerous iterations and has the possibility of no convergence, which will result in an unreasonable answer. With all nonlinear fits, it is important to make sure the resulting value is reasonable based on the data presented in the graph. This method is the most time consuming; however, it will result in reproducibility of the angle of rotation measurement of ±0.1°.

HAZARD ALERTS

The chemical safety signal words used in this experiment (DANGER and WARNING) are part of the Globally Harmonized System of Classification and labeling of Chemicals (GHS). Refer to the Safety Data Sheet (SDS) that came with the chemical for proper handling, storage, and disposal information. These can also be found online from the manufacturer.

Hydrochloric acid, 12 M, HCl: **DANGER**: Causes severe skin and eye burns and damage. Harmful if swallowed or inhaled. Do not eat or drink when using this product. Do not breathe mist, vapors, or spray. May be corrosive to metals. Industrial exposure to vapors and mists is listed as a known human carcinogen by International Agency for Research on Cancer (IARC).

Invertase, enzyme: This chemical is considered nonhazardous according to GHS classifications. Treat all laboratory chemicals with caution. Prudent laboratory practices should be observed.

Sucrose, $C_{12}H_{22}O_{11}$: This chemical is considered nonhazardous according to GHS classifications. Treat all laboratory chemicals with caution. Prudent laboratory practices should be observed.

COMPOUND INFORMATION

Compound	Chemical formula	Molar mass (g/moL)	Specific rotation (°)	Melting point (°C)
sucrose	$C_{12}H_{22}O_{11}$	342.3	+66.5	186

SAMPLE DATA

Part I Specific rotation of sucrose

15% Sucrose Sample

	Trial 1	Trial 2	Trial 3	Average
Sample height (cm)	10.0	10.0	10.0	10.0
Angle of rotation, α (°)	9.40	9.40	9.41	9.40

30% Sucrose Sample

	Trial 1	Trial 2	Trial 3	Average
Sample height (cm)	10.0	10.0	10.0	10.0
Angle of rotation, α (°)	19.37	19.35	19.34	19.35

ANSWERS TO THE DATA ANALYSIS QUESTIONS

Part I Specific rotation of sucrose

1. (9.40°)/(0.15 g/mL × 1.0 dm) = 62.6°
2. (19.35°)/(0.30 g/mL × 1.0 dm) = 64.5°
3. ((66.5° – 62.6°) / 66.5°) × 100% = 5.9%

   ((66.5° – 64.5°) / 66.5°) × 100% = 3.0%

Part II Kinetics of sucrose with acid

4. It is a first order reaction based on the nonlinear fit to a single exponential decay.
5. Using a single exponential fit, the rate constant is 0.0749 min^{-1} or 0.00124 s^{-1}.

Part III Kinetics of sucrose with invertase enzyme

6. It is a first order reaction based on the nonlinear fit to a single exponential decay.
7. Using a single exponential fit, the rate constant is 4.53 hr^{-1} = 0.0756 min^{-1}.

SAMPLE GRAPHS

Part I Specific rotation of sucrose

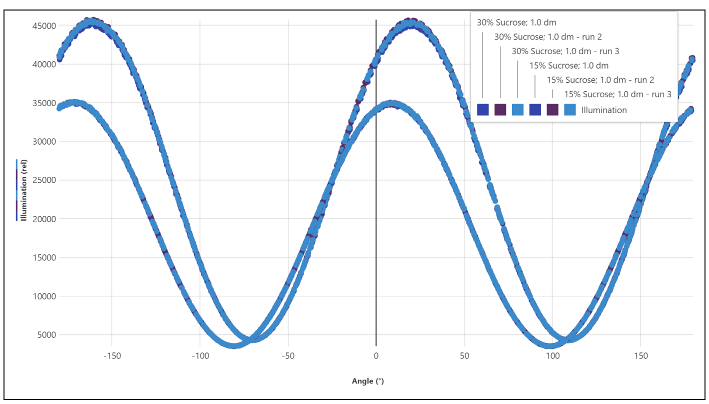

Figure 2 Raw polarimetry data for sucrose at two concentrations

Part II Kinetics of sucrose with acid

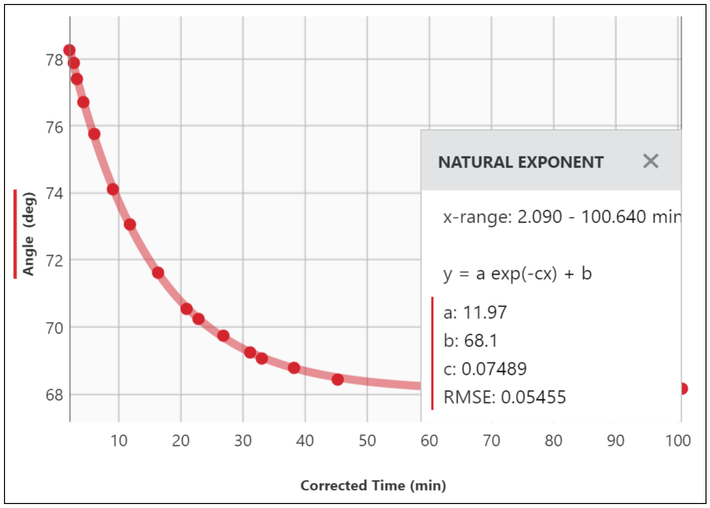

Figure 3 Kinetic trace and single exponential fit for reaction of sucrose and HCl